

Claims

What is claimed is:

1. A method of operating an engine, comprising the steps of:  
mixing fuel vapor with air in an injector;  
injecting the mixture of fuel vapor and air into an engine cylinder;  
and  
igniting the mixture in the engine cylinder.
2. The method of claim 1 wherein said mixing step includes a step of moving air from the engine cylinder into the injector.
3. The method of claim 2 wherein said moving step is performed during a compression stroke of said engine cylinder.
4. The method of claim 1 wherein said mixing step includes a step of spraying liquid fuel into a mixing chamber within said injector.
5. The method of claim 4 wherein said mixing step includes moving air into said mixing chamber during said spraying step.
6. The method of claim 4 wherein said spraying step includes a step of opening a needle valve within said injector.
7. The method of claim 1 including a step of avoiding ignition of the mixture in the mixing chamber.

8. The method of claim 7 wherein said avoiding step includes a step of lowering an air-fuel ratio in said mixing chamber below an auto-ignition level.

9. The method of claim 1 wherein said injecting step includes the steps of:

compressing said mixture; and  
opening said mixing chamber to the said engine cylinder.

10. The method of claim 9 wherein said compressing step includes a step of energizing a first electrical actuator; and  
said opening step includes a step of energizing a second electrical actuator.

11. The method of claim 9 including a step of applying a predetermined pressure to a movable piston with a pressurized actuation fluid.

12. The method of claim 11 including a step of electronically controlling said predetermined pressure.

13. The method of claim 11 wherein said actuation fluid is different from fuel fluid.

14. The method of claim 9 wherein said opening step includes a step of opening an annular passage between said mixing chamber and said engine cylinder.

15. The method of claim 1 wherein said injecting step is performed a plurality of times in one engine cycle.

16. The method of claim 15 wherein at least one of said plurality of times begins during a power stroke of said engine cylinder.

17. The method of claim 1 wherein said igniting step includes a step of compressing air in said engine cylinder above an auto-ignition level.

18. A fuel injector comprising:

an injector body having an air/fuel mixing chamber and a liquid fuel chamber disposed therein;

a first valve at least partially positioned in said injector body and fluidly positioned between said liquid fuel chamber and said air/fuel mixing chamber; and

a second valve at least partially positioned in said injector body and fluidly positioned between said air/fuel mixing chamber and an outside surface of said injector body.

19. The fuel injector of claim 18 including a first electrical actuator operably coupled to said first valve; and

a second electrical actuator operably coupled to said second valve.

20. The fuel injector of claim 19 including a first biaser operably positioned in said injector body to bias said first valve toward a closed position; and

a second biaser operably positioned in said injector body to bias said second valve toward a closed position.

21. The fuel injector of claim 18 wherein said air/fuel mixing chamber is partially defined by a displacement surface of a movable piston.

22. The fuel injector of claim 21 wherein said movable piston includes a hydraulic surface exposed to fluid pressure in a hydraulic cavity disposed in said injector body.

23. The fuel injector of claim 22 including a third valve attached to said injector body and being movable between a first position in which said hydraulic cavity is fluidly connected to a high pressure passage, and a second position in which said hydraulic cavity is fluidly connected to a low pressure passage.

24. The fuel injector of claim 23 including an electrical actuator operably coupled to said third valve.

25. The fuel injector of claim 18 wherein said injector body includes a fuel inlet and an actuation fluid inlet.

26. The fuel injector of claim 18 wherein said second valve includes a valve member with an opening hydraulic surface exposed to fluid pressure in a control chamber; and

a pressure control valve attached to said injector body and being movable between a first position that fluidly connects said control chamber to a high pressure passage, and a second position that fluidly connects said control chamber to a low pressure passage.

27. A fuel injection system comprising:  
a source of liquid fuel;

a nozzle body including an air/fuel mixing chamber at least partially disposed therein, and including a first valve fluidly positioned between said air/fuel mixing chamber and an outside surface of said nozzle body; and

a second valve movable between a first position in which said air/fuel mixing chamber is fluidly connected to said source of liquid fuel, and a second position in which said air/fuel mixing chamber is closed to said source of liquid fuel.

28. The fuel injection system of claim 27 wherein said fuel injector nozzle body is a portion of a fuel injector with said air/fuel mixing chamber disposed therein, and including a fuel inlet fluidly connected to said source of liquid fuel.

29. The fuel injection system of claim 28 including a source of actuation fluid that is different from said liquid fuel; and

said fuel injector including an actuation fluid inlet fluidly connected to said source of actuation fluid.

30. The fuel injection system of claim 29 including a first electrical actuator operably coupled to said first valve; and

a second electrical actuator operably coupled to said second valve.

31. The fuel injection system of claim 30 wherein said air/fuel mixing chamber is partially defined by a displacement surface of a movable piston.

32. The fuel injection system of claim 31 wherein said movable piston includes a hydraulic surface exposed to fluid pressure in a hydraulic cavity least partially disposed in said fuel injector.

33. The fuel injection system of claim 32 including a third valve movable between a first position in which said hydraulic cavity is fluidly connected to said actuation fluid inlet, and a second position in which said hydraulic cavity is fluidly closed to said actuation fluid inlet.

34. The fuel injector of claim 33 including an electrical actuator operably coupled to said third valve.

35. The fuel injection system of claim 34 wherein said first valve includes a valve member with an opening hydraulic surface exposed to fluid pressure in a control chamber; and

a nozzle control valve movable between a first position that fluidly connects said control chamber to said actuation fluid inlet, and a second position that fluidly closes said control chamber to said actuation fluid inlet.

36. An engine comprising:

an engine housing having at least one cylinder;

a fuel injector attached to said engine housing, and including a nozzle tip positioned in said cylinder, and including an air/fuel mixing chamber at least partially disposed therein, and a valve fluidly positioned between said air/fuel mixing chamber and an outside surface of said nozzle tip.

37. The engine of claim 36 wherein said fuel injector includes a liquid fuel chamber at least partially disposed therein;

said valve is a first valve; and

said fuel injector includes a second valve fluidly positioned between said liquid fuel chamber and said air/fuel mixing chamber.

38. The engine of claim 36 wherein said fuel injector includes an electrical actuator operably coupled to said valve.

39. The engine of claim 36 wherein said fuel injector includes a movable piston with a displacement surface that defines a portion of said air/fuel mixing chamber.

40. The engine of claim 39 wherein said movable piston includes a hydraulic surface exposed to fluid pressure in a hydraulic cavity disposed in said fuel injector.

41. The engine of claim 40 including an actuation valve movable between a first position in which said hydraulic cavity is fluidly connected to said actuation fluid inlet, and a second position in which said hydraulic cavity is fluidly closed to said actuation fluid inlet.

42. The engine of claim 36 wherein said fuel injector includes a fuel inlet fluidly connected to a source of liquid fuel, and an actuation fluid inlet fluidly connected to a source of actuation fluid that is different from said liquid fuel.